

THE ARC-SPECTRA OF THE ELEMENTS

BORON, BERYLLIUM, GERMANIUM, PLATINUM, OSMIUM, RHODIUM,
RUTHENIUM AND PALLADIUM

BY

ROBERT R. TATNALL

DISSERTATION

SUBMITTED TO THE FACULTY OF THE JOHNS HOPKINS UNIVERSITY,
IN APPLYING FOR THE DEGREE OF DOCTOR OF
PHILOSOPHY, JUNE, 1895

THE ARC-SPECTRA OF THE ELEMENTS. I.

BORON AND BERYLLIUM.

By HENRY A. ROWLAND and ROBERT R. TATNALL.

THIS paper is intended as a preliminary notice of a series of investigations on the arc-spectra of certain of the elements which have not hitherto been carefully studied by modern methods. The investigations may be regarded as a continuation of the work upon the solar spectrum commenced several years ago by one of us, inasmuch as the ultimate object in view is the identification of some of the many lines in the spectrum of the Sun, whose origin still remains unknown.

That portion of the work here described will be confined to the visible and ultra-violet portions of the spectrum. The infra-red portion forms the subject of another investigation which is now being carried on in this laboratory, the results of which are expected to appear later on.

The plates to be used will be for the most part selected from the series made some years since in connection with the study of the solar spectrum.¹ They are mostly 19 inches in length, and were made with a six-inch concave grating of $21\frac{1}{2}$ feet radius, ruled with 20,000 lines to the inch. They comprise spectra of nearly all known elements, in both first and second orders, the latter being accompanied with the solar spectrum for purposes of comparison, according to the well-known method of Rowland.²

In studying the spectrum of any element, it is first necessary to eliminate all lines due to impurities by a careful comparison

¹ The completeness of this set of plates is partly due to financial aid received from the Bache Fund of the National Academy of Sciences, from the fund given by Miss Bruce to the Harvard Astronomical Observatory for the prosecution of astrophysical research, and from the Rumford Fund of the American Academy of Arts and Sciences.

² See AMES: "The Concave Grating in Theory and Practice," *A. and A.* **II**, 28, 1892.

with the spectra of the carbon poles, and of all elements likely to be associated with the substance under examination. This comparison is made by direct superposition of the plates, which are all to nearly the same scale, thus insuring almost perfect coincidence of corresponding lines.

The measuring engine employed has a nearly perfect screw, made according to Rowland's method,¹ with such a pitch as to measure wave-lengths directly in ten-millionths of a millimeter, a slight correction only being necessary, which depends upon the plate, and its position on the carriage of the engine.

The basis of all the measurements is the Table of Standard Wave-Lengths.² As a means of determining the correction to be applied in each case, numerous standard lines selected from the Table are measured, in addition to those of the element which is being studied. Many of these standards occur on every plate, due to impurities in the carbon poles or in the material introduced into them. From the standards a correction-curve is plotted for each plate, due attention being given to the heights assigned in the Table, and to the character of the lines as affecting the accuracy of setting the cross-wires upon them. Corrections derived from the curve are then applied to the lines whose wave-lengths are required. The final value for the wave-length of any line is usually the weighted mean of several independent measurements, frequently upon different plates, and in the spectra of both first and second orders.

The intensities given in the tables are estimated, in the case of the arc-spectra, upon an ascending scale from 1 to 1,000, in which 1 indicates a line so faint as to be *just* plainly visible on the plates.

Notes marked (R) are by Professor Rowland.

The intensities assigned to lines in the Sun, where these exist, are rather uncertain estimates, in which as a means of reference D₂ is taken as 300, and the Ni line at 5893.1, at 60.

¹ See *Encyclopædia Britannica*, Art. "Screw."

² ROWLAND: "A New Table of Standard Wave-Lengths." *A. and A.* 12, 321, 1893.

BORON.

(Preliminary;—*w.-l.* 2100 to 4400).

Wave-Length	Intensity and Character	Remarks	Intensity in Sun
2496.867	65 r ¹		
2497.821	80 r		

Within the assigned limits, these two lines, forming a pair (given in the Table of Standard Wave-Lengths), appear to be the only representatives of the line-spectrum of boron, although the whole region is more or less densely filled with a band-spectrum, probably due to a compound such as boracic acid.

BERYLLIUM.

(Preliminary;—*w.-l.* 2100 to 4600).

Wave-Length	Intensity and Character	Remarks	Intensity in Sun
2175.072 ²	2		
2348.697	50 r	Possibly double, with components 0.346 apart.	
2350.855	7		
2494.532	40 } d s		
2494.960	40 } s		
2650.414	45 } d s		
2651.042	45 } s		
2898.352 ²	1		
2986.187 ²	3 }		
2986.546 ²	2 }		
3130.546	60 }	Coincides with a fine line in the Sun (R).	4 3
3131.194	60 }	Coincides with one-half of a broader solar line.	5 n
3321.219	45 }	The latter is therefore probably double (R).	
3321.487	45 }		
3367.719 ²	3 n		
4572.869	45 s		

¹ r indicates *reversed*.² Possibly not due to beryllium.³ On this scale the standard Zr line λ 3129.882 has the intensity 3.r indicates *reversed*.d indicates *double*.s indicates *sharp*.n indicates *hazy or nebulous*.

A few faint lines, difficult to identify, and indicated thus (²), do not *certainly* belong to beryllium. As a rule these do not occur in the second order spectrum. A careful comparison with the spectra of elements likely to be associated with beryllium has shown that they do not belong to C, Si, Ca, Al, Fe, Mn, Mg, Sn, As, Ce.

JOHNS HOPKINS UNIVERSITY,
November 28, 1894.

THE ARC-SPECTRA OF THE ELEMENTS. II.

By HENRY A. ROWLAND and ROBERT R. TATNALL.

GERMANIUM.

(*w.-l.* 2300 to 4600.)

Wave-length	Intensity and Character	Remarks	Intensity in Sun
2314.305	4		
2328.014	5		
2338.732	2		
2379.234	8		
2394.185	2		
2397.999	4		
2417.450	20		
2498.081	10	Close to boron line.	
2533.331	18		
2556.404	8		
2589.274	18		
2592.636	70		
2644.297	12	Also claimed by titanium.	
2651.219	100	} Possibly a single reversed line.	
2651.709	80		
2691.446	80		
2709.734	90		
2740.535	20		
2754.698	90		
2794.045	15		
2829.102	15		
3039.198	100 r		5
3067.138	7	Coincides with <i>edge</i> of a broad solar line.	1 ?
3124.945	25 s		
3269.628	60		2
3626.202	4 n		
4226.724	7 s	Close to calcium line.	

r indicates *reversed*.

s indicates *sharp*.

n indicates *hazy* or *nebulous*.

d indicates *double*.

The germanium spectrum was obtained from argyrodite, which contains in addition to this element, silver, iron, mercury, zinc, and traces of indium, thallium and lead. The silver is very strong; the others weak.

We give below a series of tables representing in detail the measurements made upon the argyrodite plates at our disposal, and from these the germanium lines given in the above list have been collected by a process of exclusion of the known substances. The tables give the results of nearly all measurements made on these plates, and contain, as will be seen, not only the lines of germanium and of other elements whose spectra are not well known, where these occur, but also the lines selected from the Table of Standard Wave-lengths for the purpose of establishing the scale and plating a correction-curve for each plate used.

It was thought that the publication of these tables would be of use, inasmuch as they furnish direct comparisons between the wave-length measurements of lines due to different elements in the same region of the spectrum. Numerous iron lines have been measured on some of the plates, and these will give a ready means of comparison with the wave-length tables of Kayser and Runge, who use the iron-spectrum as their standard of reference.

The second column in the tables contains the wave-lengths as read direct from the measuring engine. In spectra of the first order, these numbers are of course double the original readings, since the screw of the engine was made to correspond to the scale of second-order spectra. They are in many cases the means of several readings upon individual lines, or upon the lines and their ghosts, where these occur with sufficient distinctness to be used to advantage. The column headed "Standard" contains the fractional part of the wave-lengths of standard lines, as taken from the Table of Standard Wave-lengths, and the correction-curve for the plate was platted from the weighted differences between these values and those obtained with the measuring-engine. Corrections for all the lines were then found from this curve, and appear in the column headed "Correction." In the next column to this are given the corrected values of the wave-lengths, and where any line occurs on more than one plate, weights have been assigned, depending in general on the order

of the spectrum, the sharpness of the line, its distance from the end of the plate, and to some extent on the character of the correction-curve.

ARGYRODITE.—PLATE I.

FIRST ORDER SPECTRUM.

Line	Wave-length (uncorrected)	Standard	Correction	Wave-length (corrected)	Weight
Ge	2314.260		+.045	2314.305	
Ge	2327.976		+.038	2328.014	
Ge	2338.700		+.032	2338.732	
Al	2367.146	.144	+.018	2367.164	
Ge	2379.220		+.014	2379.234	
In	2389.570		+.007	2389.577	
Ge	2394.180		+.005	2394.185	
Ge	2397.996		+.003	2397.999	
In?	2399.340		+.003	2399.343	
Ge	2417.456		— .006	2417.450	
Si	2435.252	.247	— .014	2435.238	
C	2478.680	.661	— .032	2478.648	
B	2496.896	.867	— .038	2496.858	
Ge	2498.120		— .039	2498.081	
Si	2519.348	.297	— .047	2519.301	
Ge	2533.384		— .052	2533.331	
Ge	2556.464		— .060	2556.404	
Tl	2580.356		— .067	2580.289	
Ge	2589.344		— .070	2589.274	
Ge	2592.708		— .072	2592.636	
Fe	2599.558	.494	— .072	2599.486	
Ge-Ti	2644.380		— .083	2644.297	
{ Ge	2651.304		— .085	2651.219	
{ Ge	2651.794		— .085	2651.709	
Ge	2691.536		— .090	2691.446	
Ge	2709.824		— .090	2709.734	
Fe	2719.218	.119	— .090	2719.128	
Fe	2721.080	0.989	— .090	2720.990	
Fe	2723.772	.668	— .090	2723.682	
Ge	2740.624		— .089	2740.535	
Ge	2754.786		— .088	2754.698	
Tl	2768.078		— .087	2767.991	
Ge	2794.130		— .085	2794.045	
Mg	2795.700	.632	— .085	2795.615	
Mg	2802.890	.805	— .084	2802.806	
Ge	2829.182		— .080	2829.102	
Mg	2852.328	.239	— .077	2852.251	
Si	2881.760	.695	— .074	2881.686	1
Tl	2918.518		— .068	2918.450	
Fe	2967.098	.016	— .057	2967.041	1
Fe	2973.384	.358	— .056	2973.328	
Si	2987.840	.766	— .053	2987.787	
Ge	3039.260		— .040	3039.220	2
Fe	3047.774	.720	— .037	3047.737	

ARGYRODITE.—PLATE II.

SECOND ORDER SPECTRUM.

Line	Wave-length (uncorrected)	Standard	Correction	Wave-length (corrected)	Weight
Fe	3001.015	.070	+.052	3001.067	4
Fe	3021.156	.191	+.036	3021.192	
Ge	3039.173		+.023	3039.196	
Ge	3067.133		+.005	3067.138	
Al	3082.276	.272	— .003	3082.273	
Ti	3088.163	.137	— .007	3088.156	
Al	3092.830	.824	— .008	3092.822	
Ge	3124.968		— .023	3124.945	
Ca	3159.030	8.994	— .036	3158.994	
?	3225.968		— .054	3225.914	
Cu	3247.727	.671	— .057	3247.670 ¹	
Ge	3269.689		— .061	3269.628	
Cu	3274.151	.090	— .061	3274.090 ¹	
Ag	3280.880		— .063	3280.817 ¹	
Fe	3306.550	.481	— .065	3306.485	3
Ag	3383.114		— .070	3383.044 ¹	

¹ These two copper lines and two silver lines are easily reversed, and appear in the solar spectrum, being the only ones in their respective spectra which do appear there. This is owing to the fact that their intensities are so enormously greater than those of the other lines

ARGYRODITE.—PLATE III.

SECOND ORDER SPECTRUM.

Line	Wave-length (uncorrected)	Standard	Correction	Wave-length (corrected)	Weight
Ag	3382.980		+.074	3383.054	1
Fe	3440.708	.756	+.047	3440.755	
Fe	3475.567	.602	+.033	3475.600	
Fe	3490.698	.724	+.027	3490.725	
Fe	3570.252	.253	+.003	3570.255	
Fe	3581.349	.344	.000	3581.349	
Fe	3609.026	.015	— .006	3609.020	
Fe	3618.927	.922	— .008	3618.919	
Ge	3626.211		— .009	3626.202	
Fe	3631.621	.616	— .009	3631.612	
Fe	3648.004	7.995	— .012	3647.992	
Ti	3653.647	.639	— .012	3653.635	
Fe	3680.079	.064	— .014	3680.065	
Fe	3720.099	.082	— .017	3720.082	
Fe	3737.300	.280	— .017	3737.283	

ARGYRODITE. — PLATE IV.

SECOND ORDER SPECTRUM.

Line	Wave-length (uncorrected)	Standard	Correction	Wave-length (corrected)	Weight
Si ¹	3905.688	.670	— .005	3905.683	
Ca (K)	3933.814	.809	— .013	3933.801	
Al	3944.180	.165	— .015	3944.165	
? ?	3944.861		— .015	3944.846	
? ?	3944.951		— .015	3944.936	
Al	3961.700	.680	— .019	3961.681	
Ca (H)	3968.641	.617	— .021	3968.620	
Fe	4046.010	5.975	— .031	4045.979	
Fe	4063.780	.755	— .033	4063.747	
Sr	4077.907	.876	— .034	4077.873	
C ²	4197.288	.256	— .030	4197.258	
Sr	4215.714	.688	— .026	4215.688	I
Ge	4226.754		— .023	4226.731	I
Ca	4226.920	.898	— .023	4226.897	I

¹ This silicon line is by far the most important line of its spectrum that appears in the Sun.

² Head of second series of 4216 band.

ARGYRODITE. — PLATE V.

SECOND ORDER SPECTRUM.

Line	Wave-length (uncorrected)	Standard	Correction	Wave-length (corrected)	Deduced w.-l. of overlapping third order lines	Weight
Sr	4215.696	.688	— .011	4215.685		2
Ge	4226.737		— .016	4226.721		3
Ca	4226.902	.898	— .016	4226.886		3
Cr	4254.536	.494	— .025	4254.511		
Fe	4271.960	.920	— .031	4271.929		
Fe	4308.112	.072	— .044	4308.068		
Si	(4322.582)	(.543)	— .048	(4322.534)	2881.689	4
Fe	4325.982	.932	— .049	4325.933		
Fe	4383.777	.721	— .061	4383.716		
Ca	4435.196	.133	— .067	4435.129		
Fe	(4450.595)	(.524)	— .067	(4450.528)	2967.019	3
Ca	4455.021	4.949	— .068	4454.953		
Fe	(4531.201)	(.139)	— .070	(4531.131)	3020.754	
Ba	4554.274	.212	— .070	4554.204		
Ge	(4558.847)		— .070	(4558.777)	3039.185	3

THE ARC-SPECTRA OF THE ELEMENTS. III.

PLATINUM AND OSMIUM.

By HENRY A. ROWLAND and ROBERT R. TATNALL.

SINCE the appearance of the second part of the present paper in Vol. I., No. 2, of THE ASTROPHYSICAL JOURNAL, the ultra-violet spectra of some of the metals of the platinum group have been studied, mostly in the region between λ 3000 and λ 4600. The measurements have all been made upon plates containing second-order spectra.

Owing to the extreme difficulty experienced by the chemist in separating the members of this group from one another, the spectra upon our plates are very impure, and those of rhodium, ruthenium, and palladium, in particular, are much confused, so that the spectrum of either of these metals contains most of the principal lines of the other two. While this fact has very greatly increased the difficulty and uncertainty of identifying the lines, it has also added much to the accuracy of the measurements, since many of the heavier lines have been measured upon several different plates. The wave-lengths given in the following tables are the means of all measurements.

The heavier lines have been examined as to the probability of their occurrence in the solar spectrum, and the investigation has confirmed the existence of rhodium and palladium in the Sun. Ruthenium is doubtful, and it is most probable that there are no solar lines of appreciable intensity belonging to platinum or osmium, in this region of the spectrum. The most intense lines in the arc-spectra of rhodium and palladium correspond to extremely weak solar lines, and for this reason it seems best to defer a careful identification of these until after the completion of Rowland's Table of Solar Spectrum Wave-lengths, since a direct comparison of wave-length readings with those to be found in that table will give more certain results than can be

obtained by the use of Rowland's map, or by comparison of plates.

Beryllium.—Owing to an error in the preparation of the table of wave-lengths of beryllium lines (ASTROPHYSICAL JOURNAL, Vol. I., p. 16), the wave-lengths there given should read as follows:

2175.102	2986.177
2348.698	2986.547
2350.855	3130.556
2494.532	3131.200
2494.960	3321.218
2650.414	3321.486
2651.042	3367.720
2898.352	4572.869

PLATINUM.

(W.-l. 3000 to 4600.)

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
2998.079	15 r ¹	3252.103	4	3476.900	3	3681.229	2
3002.388	5 s	3256.038	5	3483.561	6	3683.123	3
3017.983	2 s	3259.859	3	3485.411	7	3687.554	3
3036.562	4	3261.819	2	3491.141	2 n	3700.059	5
3042.745	5 r	3268.570	3	3498.308	1	3706.667	7
3059.749	3	3282.097	3	3505.835	1 n	3717.982	2
3064.824	15 r	3283.332	2 }	3514.887	3	3818.827	4
3072.042	4	3283.436	2 }	3528.691	3	3898.886	3
3100.136	5 s	3290.370	6	3587.555	3	3900.874	4
3101.070	3	3301.906	12	3611.060	3	3911.050	2
3139.505	7	3315.182	5	3621.812	2	3923.106	2
3156.683	6	3323.921	4	3627.226	1	3925.486	4
3200.830	6	3344.037	3	3628.272	10 s	3948.539	5
3204.161	8	3367.135	4	3629.017	5	3959.170	2
3212.493	1	3408.277		3638.944	8 s	3966.504	12
3227.290	1	3426.880		3643.313	8	3996.722	3
3230.406	4	3428.110		3659.564	2	4012.016	2
3233.541	4	3432.023		3663.242	3	4047.796	4
3240.323	3	3454.285	2	3672.142	10 s	4054.925	2
3250.475	3	3464.080	1 n	3674.191	9 s	4066.094	2

¹ In all the tables,

r indicates *reversed*,

s indicates *sharp*,

n indicates *hazy* or *nebulous*.

PLATINUM.—*Continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4069.850	2	4192.589	5	4340.002	2	4391.996	10
4081.627	2	4205.015	4	4346.983	7	4442.723	20 s
4092.421	2	4227.523	4	4358.025	4	4445.713	5
4095.030	4	4252.229	3	4370.483	10	4498.930	4
4118.838	16 s	4288.217	2	4379.184	8	4552.594	12
4132.544	3	4327.230	10	4382.243	3	4554.828	12
4164.722	6						

OSMIUM.

(W.-l. 3000 to 4600.)

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
3018.155	5	3930.138	5	4053.407	2	4251.331	1
3041.023	3	3931.660	3	4055.641	2	4252.690	1
3058.766	5	3938.739	6	4066.464	2	4260.993	25
3077.841	3	3939.708	4	4066.848	15	4264.903	3
3156.384	5	3949.921	4	4071.008	5	4269.521	2
3232.195	3	3952.911	3	4071.162	3	4269.767	4
3268.078	5	3960.653	3	4071.716	5	4270.945	2
3301.708	8	3961.163	5	4073.763	5	4275.064	2
3336.301	3	3963.777	10	4074.834	5	4277.302	3
3370.730	3	3965.112	3	4088.593	2	4281.529	1
3402.001	2	3969.835	5	4090.922	3	4286.056	4
3402.654	1	3975.598	3	4091.977	8	4294.113	10
3445.699	2	3977.391	10	4097.004	3	4296.383	3
3449.346	3	3979.521	2	4097.090	3	4297.538	1
3504.815	3	3988.343	4	4098.264	2	4299.856	1
3598.264	3	3988.783	2	4100.446	4	4305.440	1
3640.484	3	3991.640	2	4112.185	12	4309.041	2
3654.639	2	3995.096	2	4124.762	4	4311.560	10
3657.053	3	3996.972	2	4129.124	8	4317.743	1
3671.040	3	3999.103	2	4135.945	20	4319.502	2
3790.244	3	4003.652	5	4138.013	3	4326.416	5
3794.054	2	4004.193	5	4152.455	10	4328.840	9
3876.971	3	4005.327	7	4158.948	2	4338.919	3
3895.023	2	4015.211	2	4172.710	4	4342.678	1
3895.305	3	4018.430	5	4173.386	8	4351.691	3
3900.527	4	4033.095	2	4175.781	5	4354.626	2
3901.843	5	4035.250	2	4190.052	4	4358.153	2
3918.888	2	4036.634	2	4201.528	3	4358.304	2
3919.107	2	4038.017	3	4212.007	6	4365.837	8
3925.244	3	4038.782	2	4218.991	1	4370.824	4
3926.916	3	4042.073	6	4226.675	3	4377.068	1
3928.554	3	4048.197	4	4233.613	4	4391.242	2
3928.681	3	4051.580	2	4241.679	1	4395.042	9

OSMIUM.—*Continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
4397.427	3	4437.257	2	4466.121	1	4548.827	2
4400.747	2	4439.810	2	4479.976	2	4550.571	4
4402.904	4	4445.850	1	4484.930	3	4551.463	3
4404.378	2	4447.520	5	4488.766	2	4616.944	1
4420.633	20	4459.658	1	4525.035	1		
4432.582	3	4459.781	2	4529.842	1		
4436.488	5	4462.470	1	4540.087	1		

THE ARC-SPECTRA OF THE ELEMENTS. IV.

RHODIUM, RUTHENIUM AND PALLADIUM.

By HENRY A. ROWLAND and ROBERT R. TATNALL.

WE give below the results of our measurements of the wave-lengths of violet and ultra-violet lines of Rhodium, Ruthenium and Palladium, thus completing the present series of measurements, of which previous portions have appeared in THE ASTROPHYSICAL JOURNAL for January, February and October, 1895.

As before, the following abbreviations are used in the tables: r indicates *reversed*; s indicates *sharp*; n indicates *hazy*.

RHODIUM.

(W.-l. 3000 to 4500.)

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
2986.321	4	3263.268	5	3360.038	3	3435.039	20 r
3004.555	2	3271.736	5	3360.947	4	3440.671	12
3024.019	3	3280.664	5	3362.330	2	3442.775	2
3076.006	6	3281.822	3	3368.918	1	3447.883	4
3084.081	5	3282.455	5	3372.391	6	3448.723	3
3100.407	2	3283.695	8	3372.668	1	3450.435	4
3100.556	2	3289.266	4	3377.282	3	3451.298	3
3115.026	2	3289.750	2	3377.856	2	3455.365	6
3121.873	3	3294.404	3	3381.589	1 †	3455.571	3
3123.814	4	3296.842	2	3385.924	3	3457.216	4
3137.824	2	3300.593	4	3389.361	2	3458.072	5
3152.719	1	3302.712	5	3391.927	1 †	3462.184	20 r
3155.893	3	3303.068	4	3395.040	1	3469.770	8
3179.843	2	3323.228	15	3396.960	20 r	3470.805	16 r
3185.710	2	3331.230	2	3399.839	5	3472.393	7
3189.164	4	3331.381	2	3406.694	3	3474.920	15 r
3191.305	6	3338.687	4	3407.883	2	3478.640	2
3194.660	1	3343.039	2	3412.417	5	3479.053	15 r
3197.248	4	3344.340	2	3420.312	2	3484.184	4
3214.440	2	3345.156	10	3422.434	2	3487.363	2
3237.777	2	3345.707	4	3424.532	7	3487.609	2
3261.175	2	3346.071	1	3432.238	2	3491.218	2 †

† Not certainly due to Rhodium.

RHODIUM.—Continued.

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
3491.353	3	3662.018	5	3818.339	4	4129.054	10 r
3494.591	3	3666.366	8	3822.399	15 r	4135.445	13 r
3498.878	10	3667.065	7	3828.615	15 r	4137.025	1
3502.674	25 r	3673.710	2 ¹	3834.020	15 r	4154.521	4
3505.558	4	3674.916	5	3834.895	3	4158.634	2
3507.466	12 r	3679.353	2 ¹	3856.165	4	4177.803	2
3511.691	2	3681.184	7	3856.654	20 r	4196.661	7
3511.940	3	3683.030	2 ¹	3870.151	5	4206.777	3
3513.258	3	3683.615	4 ²	3872.532	3	4211.304	20 r
3519.692	3	3690.853	10 r	3877.482	4	4218.153	1
3525.808	4	3691.477	3	3886.470	3	4221.362	1
3528.177	25 r	3692.502	40 r	3904.359	2	4230.358	2
3530.536	2	3695.099	2	3912.964	2	4244.599	3
3538.293	4	3695.669	7	3913.648	4	4258.617	1
3538.391	3	3698.410	5	3922.337	5	4260.706	1
3542.065	6	3698.742	5	3934.368	15 r	4273.581	4
3544.097	5	3699.458	3	3935.120	4	4276.974	2
3549.689	6	3701.056	30 r	3935.983	6	4278.755	4
3550.145	2	3709.773	2	3942.059	8	4288.867	10 r
3564.282	5	3713.172	5	3959.009	20 r	4296.931	5
3570.333	10	3713.575	4	3964.688	3	4308.988	2
3583.252	20 r	3714.975	4	3975.465	5 ¹	4315.123	3
3583.683	4	3735.429	7	3984.556	5	4325.578	1
3590.678	3	3736.295	4	3995.766	5	4336.176	1
3596.185	5 ¹	3737.421	5	3996.307	6	4342.604	4
3597.294	20 r	3744.325	5	4023.301	4	4345.245	2
3598.051	5	3748.362	8	4048.571	3	4345.626	3
3602.182	2	3754.268	5	4049.200	2	4349.333	2
3606.019	8	3754.431	5	4053.603	2	4373.212	6
3608.243	2	3755.736	3	4056.503	2	4374.981	45 r
3612.618	8	3760.559	3	4077.748	4	4376.347	1
3614.931	6	3765.227	10 r	4080.699	1	4380.082	8
3620.605	7	3770.125	5	4081.975	2	4388.215	2
3626.744	12	3778.279	5	4082.949	10	4402.716	1
3627.334	3	3788.624	8 h	4084.450	2	4423.824	1
3627.957	4	3793.364	5 r	4087.948	2	4424.217	2
3639.662	7 ²	3799.461	10 r ³	4088.651	2	4433.489	3
3651.505	2	3806.070	4	4097.692	6	4492.643	4
3654.569	1	3806.908	5	4107.665	4	4503.955	3
3655.026	10	3809.648	3	4116.496	4	4528.901	7
3656.994	2	3812.603	3	4119.852	5	4569.184	4
3658.135	25 r	3815.166	3	4121.855	9 r		
3661.748	2	3816.611	4	4125.068	1		

¹ Not certainly due to Rhodium.² Superposed on Pb line.³ Distinct from Ru 3799.489.

RUTHENIUM.

(W.-l. 2975 to 4200.)

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
2974.095	2	3096.669	4	3238.600	3	3344.679	2
2974.457	1	3097.337	1	3239.727	2	3345.457	2
2976.700	3	3097.708	2	3241.360	3	3347.757	2
2977.037	4	3099.390	4	3243.632	3	3348.153	1
2979.834	2	3100.945	4	3251.450	1	3348.847	2
2980.056	2	3105.523	1	3252.020	1	3352.075	2
2982.048	2	3106.954	1	3253.041	2	3353.790	2
2989.061	5	3107.825	2	3254.670	3	3359.239	5
2989.768	1	3110.650	2	3254.834	3	3362.151	3
2993.385	2	3112.031	2	3256.460	2	3362.473	1
2995.077	4	3112.792	1	3258.173	2	3364.243	2
2997.006	2	3118.182	2	3259.805	2	3368.524	2
2997.536	2	3118.799	2	3260.301	1	3368.604	4
2997.730	2	3124.279	3	3260.477	5	3371.992	3
2998.458	2	3124.480	1	3261.256	1	3374.790	3
3001.751	3	3124.720	1	3263.984	1	3378.170	3
3006.699	3	3126.075	3	3264.688	2	3379.744	3
3008.366	2	3129.951	2	3264.790	2	3380.308	3
3008.906	2	3132.995	3	3268.346	4	3385.297	3
3013.030	2	3136.671	3	3273.208	4	3385.608	1
3013.468	2	3140.604	1	3274.834	4	3385.836	2
3020.985	4	3141.094	2	3277.697	3	3387.369	1
3033.564	3	3144.383	2	3285.066	3	3388.846	3
3034.169	2	3147.326	1	3294.233	4	3389.644	3
3038.284	2	3150.816	2	3296.248	3	3392.032	2
3040.420	3	3153.941	3	3296.780	3	3392.672	5
3042.587	3	3160.042	5	3297.389	2 ¹	3401.646	2
3042.944	2	3168.678	4	3298.089	3	3401.876	4
3045.828	3	3174.254	2	3298.549	2	3406.025	2
3048.603	2	3177.170	2	3299.466	2	3406.731	3
3048.900	3	3186.162	4	3304.126	2	3409.424	5
3055.039	4	3188.468	4	3304.951	2	3411.780	4
3058.891	1	3189.843	1	3306.310	4	3412.939	3
3059.275	2	3190.096	4	3311.096	2	3414.782	2
3064.951	4	3192.191	3	3315.363	4	3416.320	2
3068.363	2	3196.725	3	3315.579	2	3417.466	10 r
3071.711	1	3201.631	2	3316.524	4	3418.117	2
3073.442	4	3213.105	3	3318.025	3	3419.389	2
3076.883	2	3216.646	3	3318.965	3	3420.236	3
3081.010	3	3220.199	1	3325.136	3	3426.089	2
3083.257	1	3221.311	1	3327.843	2	3428.460	15 r
3084.637	1	3223.394	4	3332.190	2	3428.769	5
3086.182	2	3226.502	4	3332.781	2	3429.689	7
3089.259	3	3227.027	1	3335.836	4	3430.908	4
3089.916	2	3228.007	3	3339.690	6	3432.348	3
3090.348	2	3228.280	1	3341.230	2	3432.896	4
3091.980	2	3228.651	3	3341.365	1	3433.397	3
3094.507	2	3232.872	2	3341.811	3	3435.327	4

¹ Not certainly due to Ruthenium.

RUTHENIUM. *Continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
3430.475	3	3503.178	13 r	3717.822	2 ^a	3825.074	2
3430.883	20 r	3500.342	10 r	3719.408	4	3828.319	5
3438.510	5	3500.914	5	3725.117	3	3828.849	2
3440.351	5	3001.030	3	3726.239	5	3831.934	4
3440.107	1	3005.785	3	3727.073	15 r ^s	3835.191	3
3450.703	3	3008.878	4	3728.173	15 r	3838.201	3
3462.180	4 ¹	3000.247	2	3730.577	10 r	3839.832	3
3463.280	3	3017.100	3	3730.737	3	3850.561	3
3467.102	2	3019.348	3	3731.048	1	3852.260	2
3473.892	9	3020.434	2	3732.170	2 ^a	3857.680	4
3481.440	4	3025.330	4	3733.188	2	3862.819	4
3483.317	3	3026.880	4 ^a	3737.540	3	3865.547	3
3483.438	3	3027.433	2	3737.902	2	3867.962	3
3494.404	3	3031.859	3	3738.773	2	3873.660	3
3490.131	3	3034.004	3	3739.057	2	3876.229	1
3490.272	2	3035.084	12 r	3739.610	4	3884.207	2
3498.080	2	3035.058	2	3742.422	10 r	3884.849	2
3499.005	35 r	3037.612	3	3742.933	7	3887.960	2
3513.790	3	3038.101	2	3744.303	3	3890.347	3
3514.031	5	3040.780	3	3753.084	4	3891.564	2
3510.785	4	3040.202	3	3755.234	3	3892.364	5
3520.280	4	3050.405	3	3755.868	2	3892.915	1
3528.832	4	3052.400	2	3756.075	5	3897.383	2
3531.543	4	3054.540	4	3759.970	7	3898.498	2
3532.002	4	3060.901	2	3760.103	10 r	3901.391	3
3535.537	3	3061.525	10 r	3761.655	3	3908.906	2
3538.088	4	3061.721	2	3764.173	2 ^a	3909.222	5
3538.100	4	3063.520	6	3767.495	4	3912.252	2
3539.435	2	3069.688	0.8	3773.314	2	3914.990	3
3539.521	3	3071.385	2	3777.720	4	3920.060	4
3541.777	4	3072.521	2	3778.853	2	3923.615	6
3547.131	2	3075.400	1	3786.194	10 r	3924.774	2
3550.410	3	3076.808	2	3790.655	12 r	3926.062	6
3551.008	2	3077.008	1	3795.052	2	3931.920	5
3550.773	2	3078.456	4	3795.316	2	3933.700	4
3557.207	2	3080.086	2	3798.180	3	3938.060	3
3562.043	2	3093.734	2 ^a	3799.042	15 r	3941.819	2
3564.500	2	3090.725	4	3799.489	15 r	3942.215	3
3564.710	2	3097.900	2	3800.303	3	3944.339	2
3564.040	2	3701.450	2	3803.326	3	3945.730	4
3567.300	2	3702.309	2	3805.570	2 ^a	3946.468	2
3570.748	4	3703.343	2	3808.824	3	3949.560	7
3571.013	2	3705.400	2 ^a	3812.860	2	3950.183	3
3574.748	3	3712.444	3	3814.076	3 ^a	3950.371	4
3579.024	2	3715.705	3	3817.424	3	3950.556	3
3584.340	1	3719.314	3	3819.173	2	3951.360	2
3580.300	7	3717.140	4	3822.233	3	3952.844	4

¹ Distinct from Rh 3462.184.^a Not certainly due to Ruthenium.^s Also Fe.

RUTHENIUM.—*Continued.*

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
3957.600	2	4100.530	2	4226.824	2	4361.371	7
3965.055	4	4102.443	2	4229.475	3	4361.597	2
3974.650	2	4108.001	3	4230.478	5	4371.366	3
3978.600	5	4108.224	2	4232.481	3	4372.363	6
3979.571	5	4112.905	10	4236.834	3	4383.526	3
3985.007	6	4113.542	3	4241.215	6	4385.553	5
3987.942	5	4118.666	2	4243.216	7	4385.814	5
3996.128	4	4121.153	3	4244.902	4	4386.436	3
4005.793	3	4123.227	3	4246.498	3	4390.605	6
4006.748	2	4127.609	2	4246.893	4	4391.191	3
4007.686	2	4128.035	2	4259.144	5	4397.966	4
4008.418	2	4137.394	3	4265.762	2	4410.193	6
4013.652	2	4144.324	7	4277.413	2	4421.013	2
4022.315	5	4145.905	5	4278.844	2	4421.626	3
4023.986	5	4146.439	4	4282.367	2	4421.631	4
4024.847	2	4148.539	2	4282.367	3	4439.935	4
4031.155	2	4150.470	2	4284.490	6	4444.681	2
4032.362	3	4161.823	3	4287.204	4	4449.509	4
4039.365	4	4167.047	2	4293.443	4	4460.194	5
4045.949	4	4167.683	4	4294.948	4	4474.100	3
4049.570	2	4170.219	2	4296.090	4	4480.617	3
4051.561	6	4175.604	1	4297.870	10	4498.316	4
4052.354	3	4182.623	2	4307.746	6	4510.265	3
4054.212	4	4182.812	2	4314.471	3	4511.364	2
4063.023	2	4182.998	1	4316.801	2	4517.063	3
4063.147	3	4189.631	2	4318.599	4	4517.985	3
4064.263	2	4197.039	3	4320.036	5	4521.124	3
4064.615	3	4197.745	4	4325.213	4	4547.467	3
4067.771	3	4199.039	4	4326.986	4	4548.031	3
4068.529	4	4200.062	16 r	4327.590	3	4550.121	2
4071.561	2	4206.178	5	4331.329	3	4552.293	2
4073.156	3	4207.798	2	4336.591	2	4554.697	13 r
4076.886	5	4212.225	10	4337.431	4	4560.168	2
4080.757	15 r	4214.604	4	4342.236	5	4584.619	4
4085.589	3	4214.714	2	4346.645	3	4591.285	2
4091.223	3	4217.427	4	4349.867	4	4592.699	2
4097.185	3	4220.838	3	4354.296	5	4599.265	3
4097.948	6	4225.256	3	4354.969	3		

PALLADIUM.

(W.-l. 3000 to 4200.)

Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	Intensity and Character
3002.765	6	3373.139	30 r	3481.300	40 r	3662.520	4 n [†]
3028.021	9 r	3380.832	4	3486.112	2	3690.483	25 r
3065.408	9 r	3389.195	3	3489.915	20 r	3719.046	15 r [†]
3114.152	20 r	3404.725	100 r	3517.096	50 r	3799.335	10 r
3142.927	5	3406.196	3	3528.878	3	3894.334	25
3219.097	5	3419.805	5	3553.236	45 r	3958.772	25
3242.828	60 r	3421.367	50 r	3566.781	3	4087.513	10 s
3251.760	20 r	3433.578	30 r	3571.302	20 r	4170.006	6
3258.900	25 r	3441.539	25 r	3596.804	3	4213.115	15
3287.377	7	3442.548	3	3609.696	65 r	4473.761	10 s
3302.256	30 r	3460.884	35 r	3634.841	65 r		

[†] Not certainly due to Palladium.

